Mechanics of Insulator Behavior in Concrete Crosstie Fastening Systems



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Outline

- Current insulator performance
- Objectives of research
- Analysis of failure modes and causes
- Relevant material properties related to failure modes
- Preliminary testing and results
- Future work

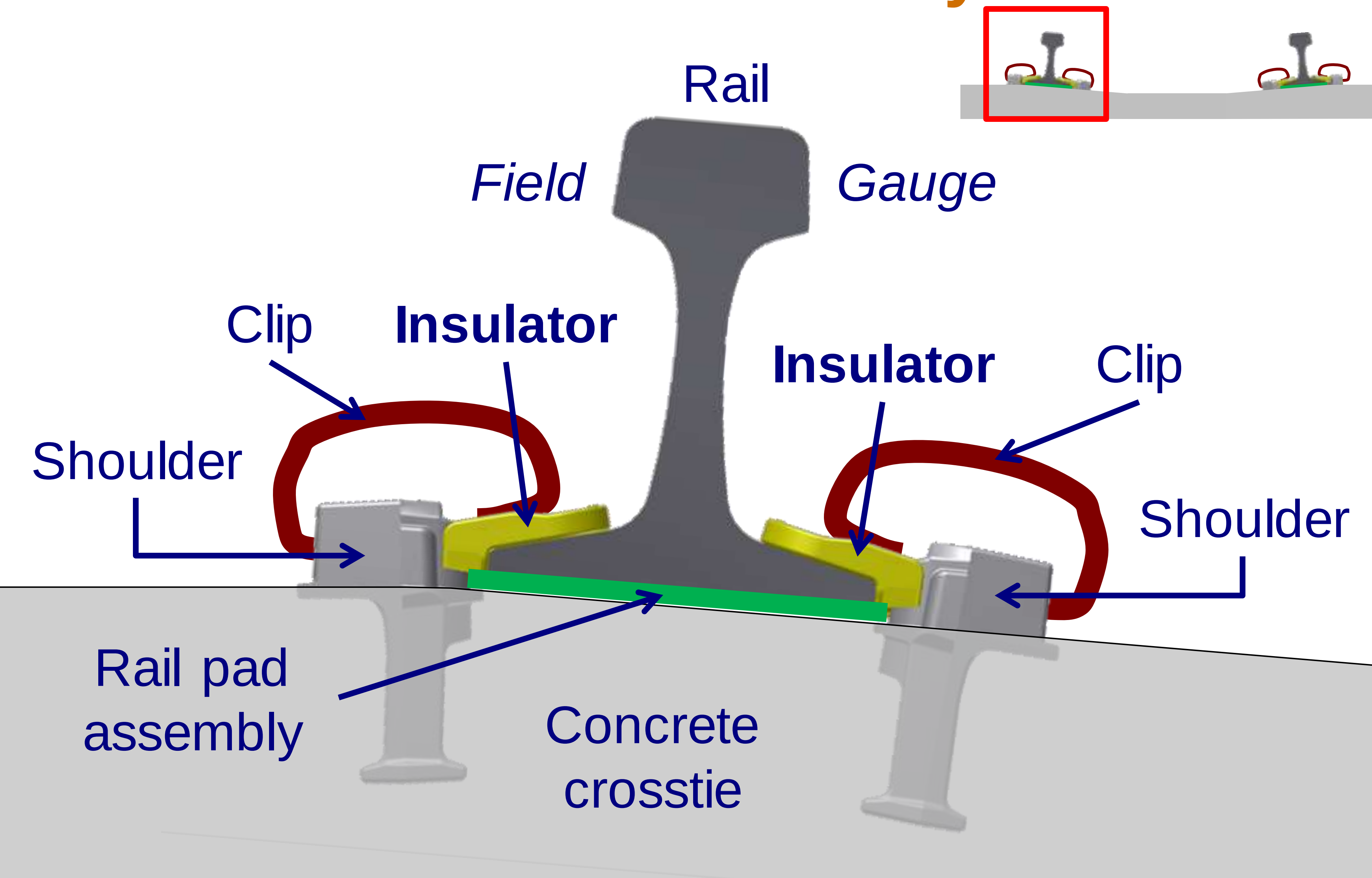
Current insulator performance

- 25 million concrete crossties in North America
- Insulator performance is not consistently meeting expectations
  - Desired life cycle of insulator is life of rail
- Failures seen predominantly in curves
- Increase life cycle by mitigating causes of failure

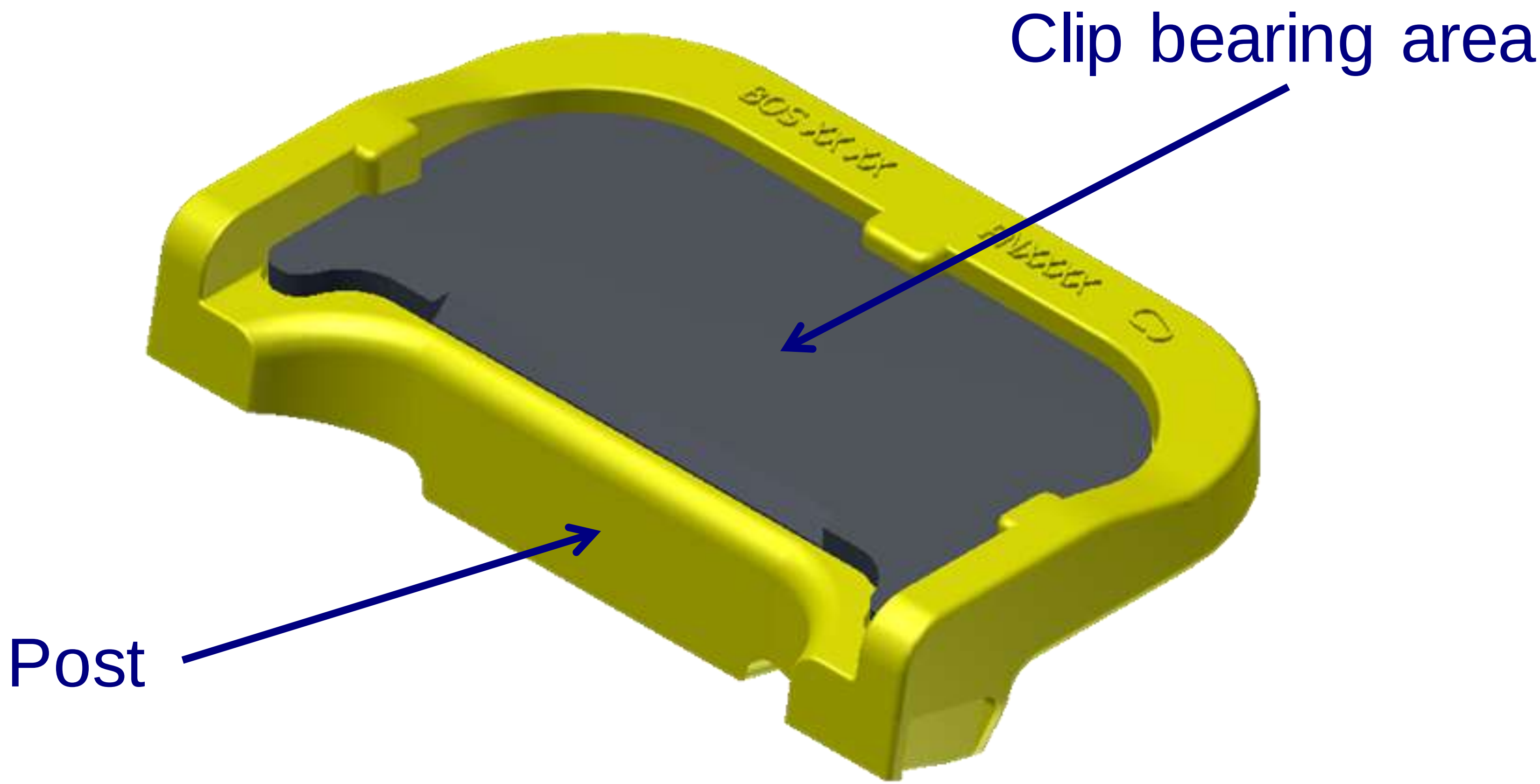
Objectives of research

- Understand the behavior of the insulator under loading conditions and environments associated with failure
  - Forces in the insulator
  - Deformation and relative slip
- Investigate innovative materials and their properties
- Find optimized designs and materials that ultimately lead to a longer service life

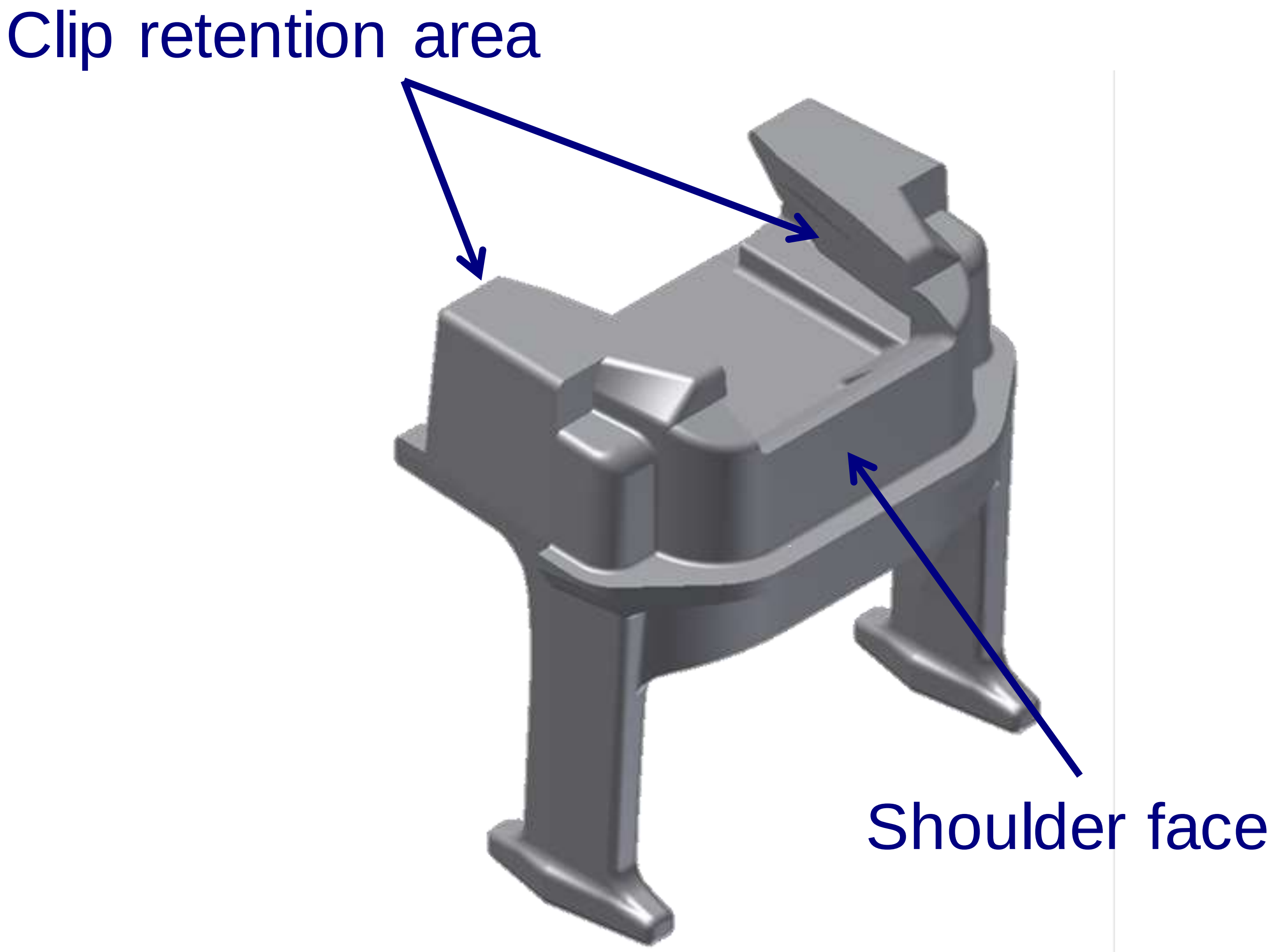
General assembly



Insulator orientation

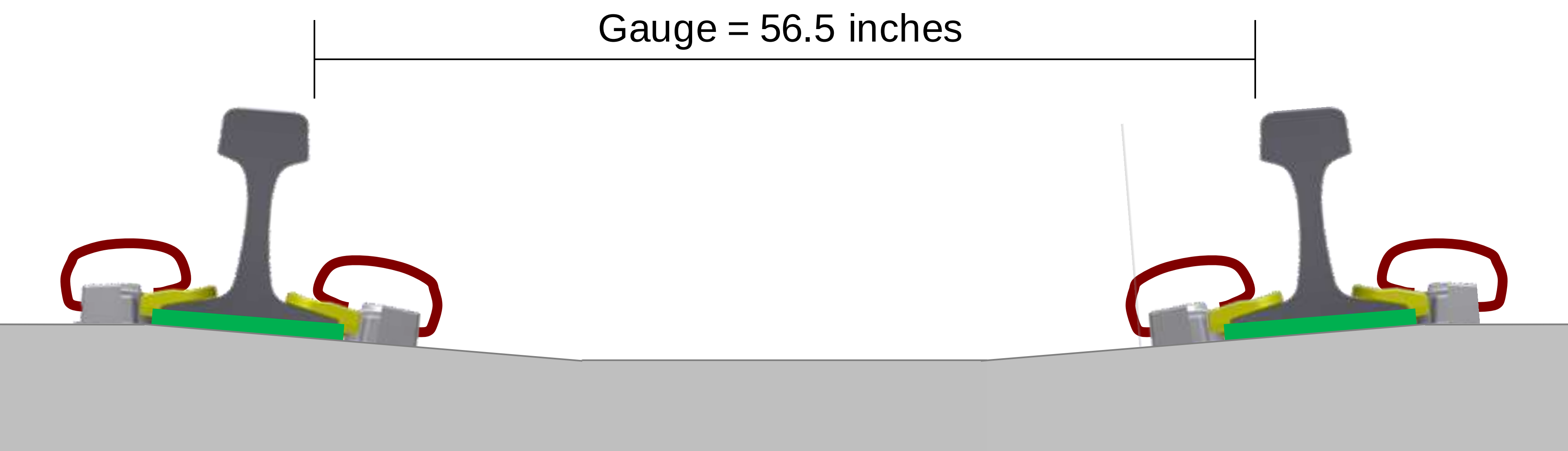


Shoulder orientation



Functions of an insulator

- Establish and maintain gauge
- Protect shoulder and attenuate load entering shoulder
- Provide electrical isolation between metallic surfaces
- Transfer clamping force from clip to rail



Analysis of failure modes and causes

- Failure Mode and Effect Analysis (FMEA) used to define and identify causes and effects of failure
- Failure results in wide gauge, shunt in track circuit, excessive rail movement, expedited wear of other components
- Potential failure mechanisms:
  - **Abrasion**
  - **Bending or deformation**
  - **Crushing**

Optimized material properties can help mitigate these failure mechanisms

Insulator failure mechanisms - abrasion

- Important material properties
  - Shear strength
  - Abrasion resistance

Insulator failure mechanisms - bending or deformation

- Important material properties
  - Flexural strength
  - Cold temperature impact

Insulator failure mechanisms - crushing

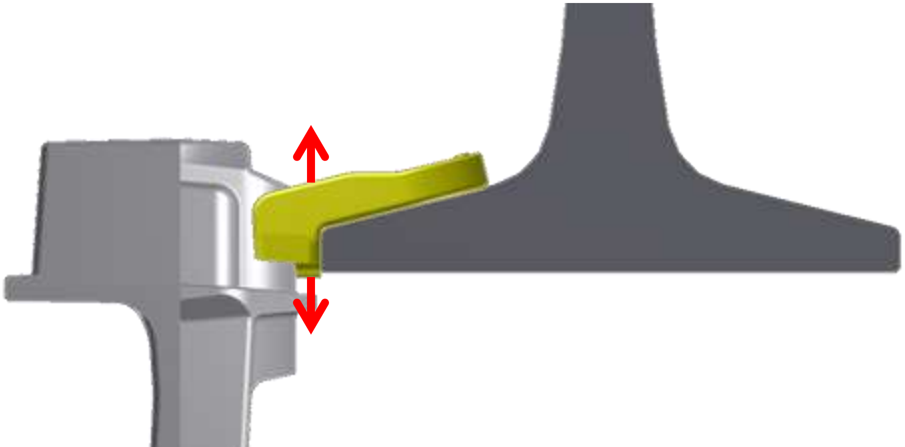
- Important material properties
  - Compressive and tensile strength

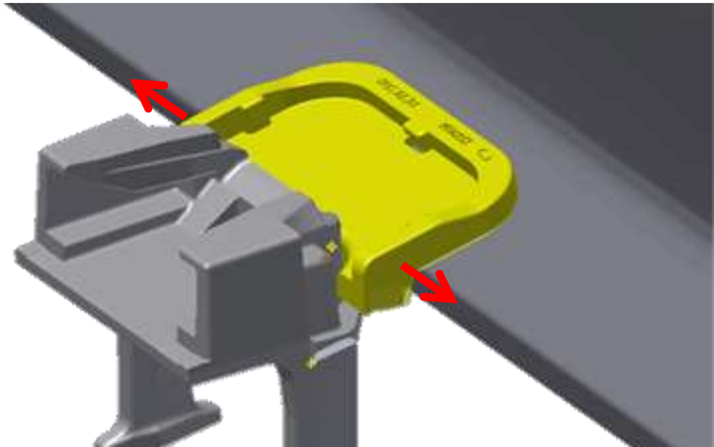
Design and performance considerations

- Environmental conditions affecting component material properties
  - Temperature
  - UV light
  - Presence of moisture
    - Nylon has a propensity to absorb moisture
- Continuous loading
  - Fatigue characteristics from passing trains
  - Creep characteristics from seating loads
- Changes in properties between manufacture and field

Quantifying insulator demands

- Quantifying force transmitted through insulator post is paramount to understanding behavior or component
  - Lateral load measurement through post
    - Compressive force
- Deformation and relative slip of insulator is also key
  - Longitudinal translation
  - Vertical post movement relative to rail and shoulder



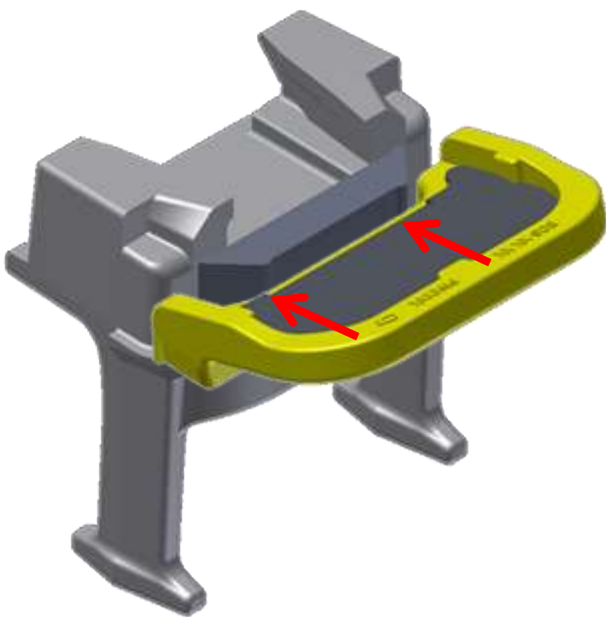


Past work – BNSF lateral load measurement

- Instrumented field and gauge side insulator post
- Measured compressive force in post on 7-10° curve
- Key findings
  - 8-10 kip lateral force needed to transfer load to adjacent ties
  - 10 kip force imparted into system due to thermal expansion of rail
  - Instrumentation failed under such high loads

Quantifying lateral load entering shoulder face

- Instrumented shoulder face insert
  - Original shoulder face is removed
  - Insert designed as a beam and optimized to replace removed section
  - Measures bending strain of beam under 4-point bending
    - Measuring bending strain is a proven technique

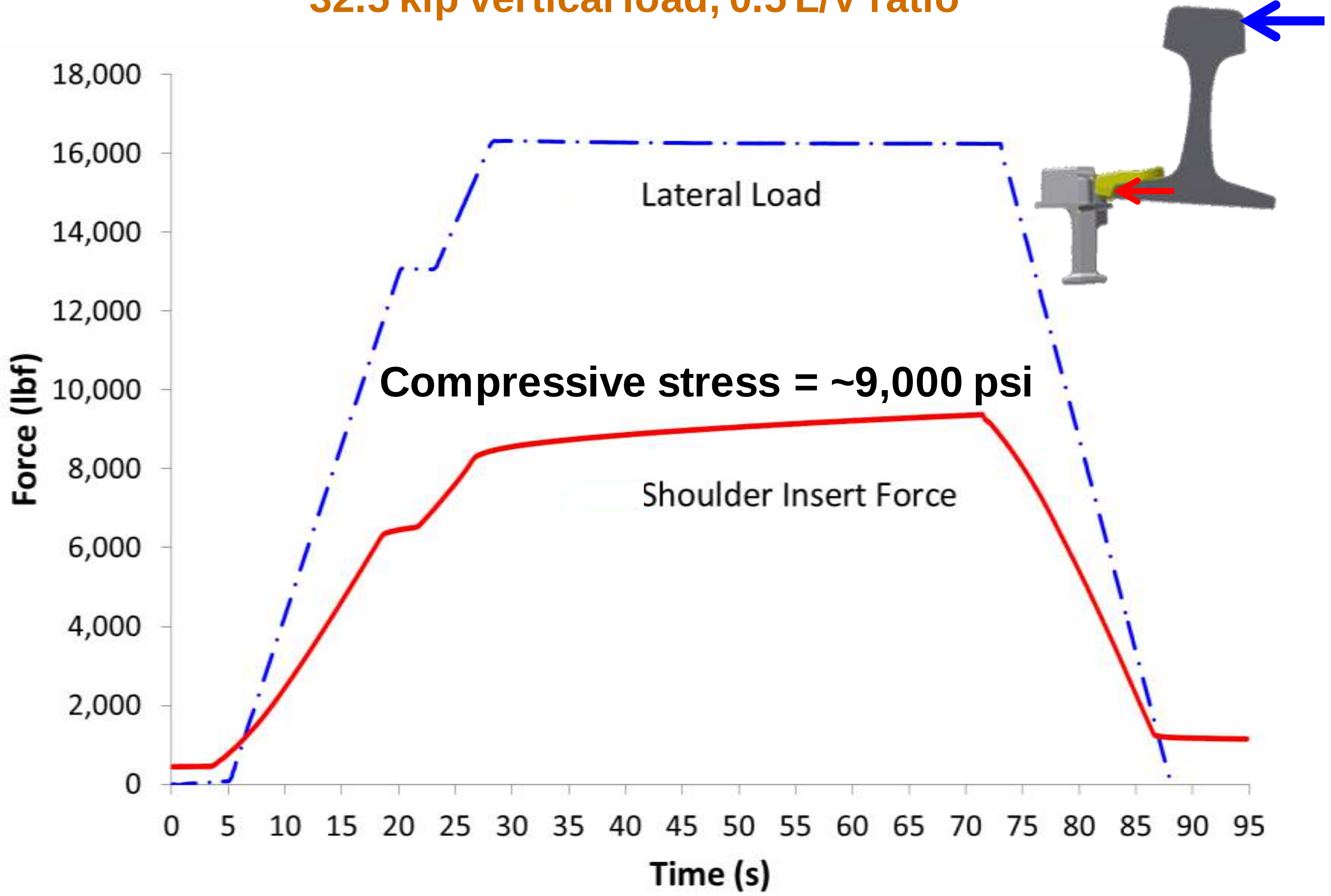


Laboratory proof of concept

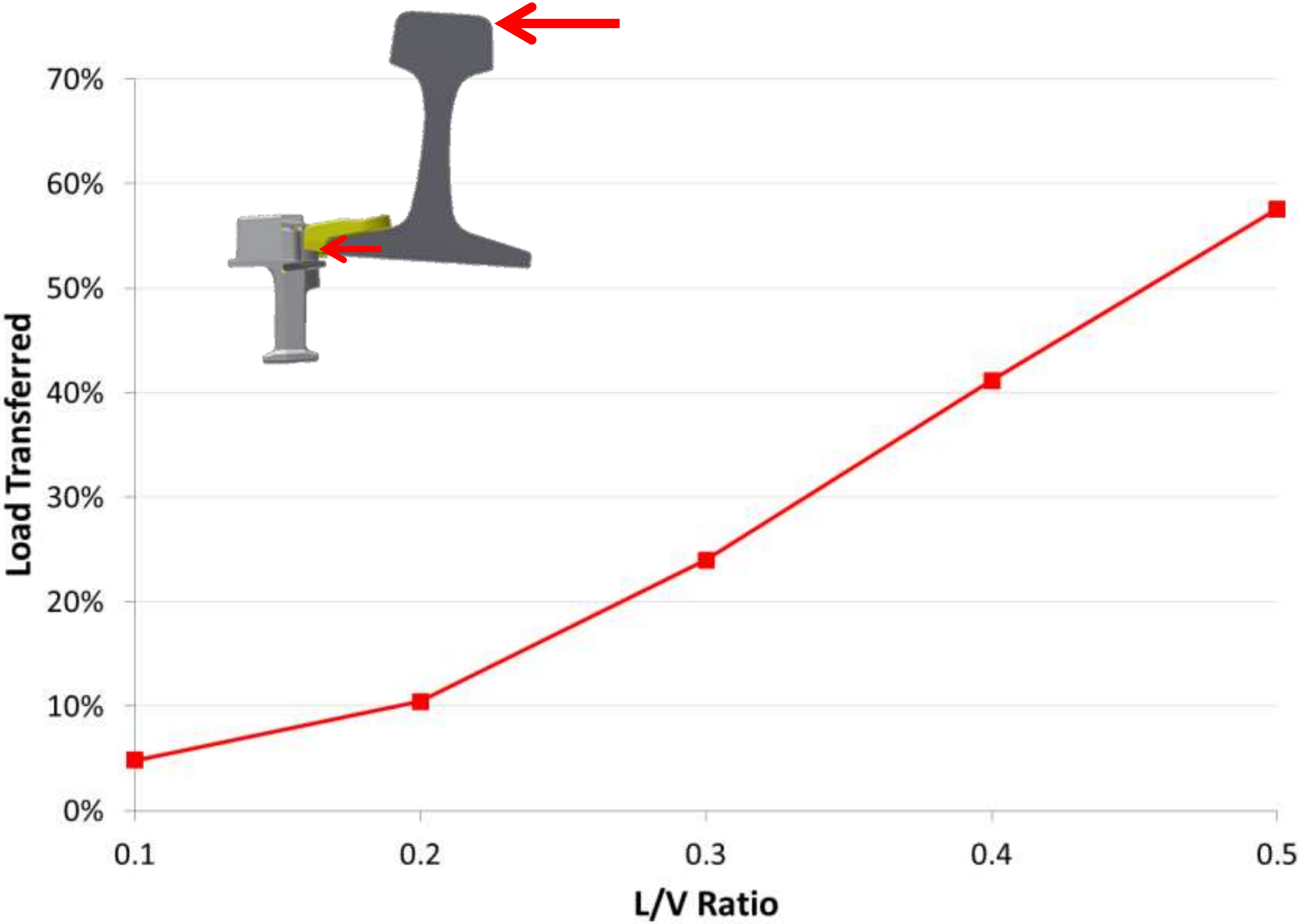
- Instrumented shoulder face insert tested on Pulsating Load Testing Machine (PLTM) at UIUC
- Varied lateral load from 1,800 to 18,000 lbf
- Varied L/V ratio from 0.1 to 0.5
- Tested dynamic loading at 3 Hz
- Representative loading conditions
  – Sharp curvature
  – Demanding conditions

Transfer of lateral load to shoulder face

32.5 kip vertical load, 0.5 L/V ratio



Transferred load through shoulder



Preliminary conclusions from testing

- Percentage of lateral load transferred through post increases as L/V ratio increases
- Lateral loads are resisted by friction at low L/V ratios
- Lower coefficients of friction between concrete tie and rail pad result in increased lateral load through post
- Reliable results can be achieved with instrumented shoulder face insert in laboratory
- Successful laboratory testing results make it a viable way to measure lateral load in the field

Future work

- Laboratory testing of lateral load measurement systems
- Laboratory testing to determine failure thresholds
- Field validation testing with lateral load measurement systems at Transportation Technology Center (TTC)
- Compare field data with lab and model data
- Measurement of lateral load on in-service track
- Determine correlations between fastening system component behavior and various material properties
- Propose optimized component materials and design

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Questions

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